



(43) International Publication Date
13 February 2014 (13.02.2014)

WIPO | PCT

(10) International Publication Number
WO 2014/025149 A1

- (51) **International Patent Classification:**
G02B 5/18 (2006.01) *G03F 7/26* (2006.01)
- (21) **International Application Number:**
PCT/KR2013/006711
- (22) **International Filing Date:**
26 July 2013 (26.07.2013)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
10-2012-0087418 9 August 2012 (09.08.2012) KR
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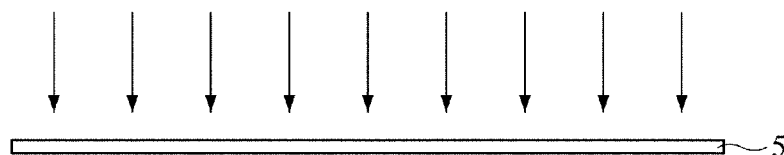
(81) **Designated States** (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) **Title:** APPARATUS AND METHOD FOR MANUFACTURING PHASE-TYPE DIFFRACTION ELEMENT USING LASER EXPOSURE TYPE



(57) **Abstract:** The present invention relates to an apparatus for manufacturing a phase-type diffraction element using a direct laser exposure method, a method of manufacturing a phase-type diffraction element, and a phase-type diffraction element using a direct laser exposure method. More specifically, the present invention relates to an apparatus and method for manufacturing a phase-type diffraction element by radiating a laser beam on a substrate formed of photo-curable resin.

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Description

Title of Invention: APPARATUS AND METHOD FOR MANUFACTURING PHASE-TYPE DIFFRACTION ELEMENT USING LASER EXPOSURE TYPE

Technical Field

- [1] The present invention relates to an apparatus for manufacturing a phase-type diffraction element using a direct laser exposure method, a method of manufacturing a phase-type diffraction element, and a phase-type diffraction element using a direct laser exposure method. More specifically, the present invention relates to an apparatus and method for manufacturing a phase-type diffraction element by radiating a laser beam on a substrate formed of photo-curable resin.

Background Art

- [2] A photo lithography method, an ion beam method, a laser exposure method and the like exist as conventional methods of manufacturing a micro pattern. Here, the ion beam method is used to manufacture a cutting-edge product or a LSI semiconductor since a micro pattern having a further minute line width can be manufactured owing to a narrow line width of an ion beam. The laser exposure method forms a micro pattern through an etching process by radiating a laser beam after coating a photosensitive film 3, physical properties of which are changed by the laser beam, on a substrate 4.
- [3] FIG. 1 is a cross-sectional view mimetically showing a laser beam 1 penetrating an exposure lens 70 and radiated on a photosensitive film 3 in the prior art. As shown in FIG. 1, a micro pattern may be manufactured by radiating the laser beam 1 penetrating the exposure lens 70 on the photosensitive film 3 and performing an etching process.
- [4] In addition, the phase-type diffraction element may be manufactured by applying a direct laser exposure method. That is, since the refractive index of photo-curable resin is changed by the strength and phase of the laser beam 1, a phase-type diffraction element having a desired refractive index can be manufactured by applying the direct laser exposure method.
- [5] Such photo-curable resin is used to manufacture a conventional lens 6. However, although a uniform refractive index is needed inside the lens 6 when the laser beam 1 penetrating the exposure lens 70 is radiated on the surface of the lens 6 formed of photo-curable resin, it is difficult to uniformly maintain output of the laser beam radiated on the surface of the lens 6.
- [6] FIG. 2 is a cross-sectional view mimetically showing a laser beam 1 penetrating an exposure lens 70 and radiated on the surface of a lens 6 formed of photo-curable resin. As shown in FIG. 2, if the exposure lens 70 is moved in parallel in the plane direction

when the laser beam 1 penetrating the exposure lens 70 is radiated on the lens 6 formed of photo-curable resin, laser output radiated at the end portion of the lens 6 formed of photo-curable resin is different from laser output radiated on the middle portion of the lens 6, and thus the lens 6 may not have a uniform refractive index. In addition, since curing the inner part of the lens 6 formed of photo-curable resin may give a bad effect of changing again curing the outer part of the lens 6, it is difficult to manufacture a lens 6 having a uniform refractive index.

[7] As a result, the photo-curable resin is used for coating purpose or for manufacturing an optical waveguide by radiating uniform light on the photo-curable resin of a plate form. FIG. 3 is a cross-sectional view showing a state of radiating a laser beam on the surface of a substrate formed of photo-curable resin.

[8] Accordingly, in addition to applying the photo-curable resin to a coating or an optical waveguide, it is required to provide a method and apparatus for manufacturing a phase-type diffraction element by applying a direct laser exposure method using characteristics of the photo-curable resin.

Disclosure of Invention

Technical Problem

[9] Therefore, the present invention has been made in view of the above problems, and it is an object of the present invention to provide a method and apparatus for manufacturing a phase-type diffraction element of a sine wave or a sawtooth wave having a desired refractive index by radiating a laser beam, which can be adjusted in quantity, on a substrate formed of photo-curable resin.

[10] The other objects, specific advantages and new features of the present invention will be further clarified from the following detailed descriptions and preferred embodiments made with reference to the accompanying drawings.

Solution to Problem

[11] To accomplish a first object of the present invention, there is provided an apparatus for manufacturing a phase-type diffraction element using a direct laser exposure method, the apparatus including: a laser generation unit for generating a laser beam having a specific width; an exposure lens for penetrating the laser beam generated by the laser beam generation unit; a substrate formed of photo-curable resin and installed at a focus of the exposure lens, on which the laser beam is radiated on, and a refractive index of which is changed by the laser beam; and a driving unit for moving the substrate or the exposure lens in a plane direction.

[12] In addition, the laser beam may be a Gaussian beam.

[13] The cross section of the Gaussian beam may have an optical strength gradually decreasing from a center toward an outer circumference.

- [14] The apparatus for manufacturing a phase-type diffraction element may further include a substrate installation unit for installing the substrate, and the driving unit may include an X-axis driving unit for moving the substrate installation unit or the exposure lens in an X-axis direction which is parallel to the plane direction.
- [15] The driving unit may further include a Y-axis driving unit for moving the substrate installation unit or the exposure lens in a Y-axis direction which is parallel to the plane direction and perpendicular to the X-axis direction.
- [16] The driving unit may further include a rotation driving unit for rotating the substrate installation unit on a Z-axis which is a vertical axis.
- [17] The apparatus for manufacturing a phase-type diffraction element may further include a control unit for controlling a moving direction and a moving speed of the X-axis driving unit, the Y-axis driving unit and the rotation driving unit.
- [18] To accomplish a second object of the present invention, there is provided an apparatus for manufacturing a phase-type diffraction element using a direct laser exposure method, the apparatus including: a laser generation unit for generating a laser beam having a specific width; a light quantity control unit for adjusting light quantity of the laser beam generated by the laser generation unit; an exposure lens for penetrating the laser beam generated by the laser beam generation unit; a substrate formed of photo-curable resin and installed at a focus of the exposure lens, on which the laser beam is radiated on, and a refractive index of which is changed by the laser beam; and a driving unit for moving the substrate or the exposure lens in a plane direction.
- [19] In addition, the light quantity control unit may include an acousto-optic modulator, a beam splitter, a photodiode and a controller.
- [20] The apparatus for manufacturing a phase-type diffraction element may further include a substrate installation unit for installing the substrate, and the driving unit may include an X-axis driving unit for moving the substrate installation unit or the exposure lens in an X-axis direction which is parallel to the plane direction.
- [21] The driving unit may further include a Y-axis driving unit for moving the substrate installation unit or the exposure lens in a Y-axis direction which is parallel to the plane direction and perpendicular to the X-axis direction.
- [22] The driving unit may further include a rotation driving unit for rotating the substrate installation unit on a Z-axis which is a vertical axis.
- [23] The apparatus for manufacturing a phase-type diffraction element may further include a control unit for controlling a moving direction and a moving speed of the X-axis driving unit, the Y-axis driving unit and the rotation driving unit.
- [24] The apparatus for manufacturing a phase-type diffraction element may further include a focus adjustment unit for adjusting the focus of the exposure lens by adjusting a distance between the exposure lens and the substrate.

- [25] To accomplish a third object of the present invention, there is provided a method of manufacturing a phase-type diffraction element using a direct laser exposure method, the method including the steps of: generating, by a laser generation unit, a Gaussian beam having a specific width; passing the Gaussian beam through an exposure lens; radiating the Gaussian beam on a substrate formed of photo-curable resin and installed at a focus of the exposure lens; changing a refractive index of the substrate on which the Gaussian beam is radiated; driving, by a control unit, any one of an X-axis driving unit for moving a substrate installation unit or the exposure lens in an X-axis direction which is parallel to a plane direction, a Y-axis driving unit for moving the substrate installation unit or the exposure lens in a Y-axis direction which is perpendicular to the X-axis direction and parallel to the plane direction, and a rotation driving unit for rotating the substrate installation unit on a Z-axis which is a vertical axis; and forming a sine wave phase diffraction grating on the substrate on which the Gaussian beam is radiated.
- [26] To accomplish a fourth object of the present invention, there is provided a method of manufacturing a phase-type diffraction element using a direct laser exposure method, the method including the steps of: generating, by a laser generation unit, a laser beam having a specific width; adjusting, by a light quantity control unit, the laser beam to have a set light quantity; passing the laser beam through an exposure lens; radiating the laser beam on a substrate formed of photo-curable resin and installed at a focus of the exposure lens; changing a refractive index of the substrate on which the laser beam is radiated; radiating the laser beam on the substrate as wide as a set moving distance by controlling, by a control unit, an X-axis driving unit which moves a substrate installation unit or the exposure lens in an X-axis direction which is parallel to a plane direction; moving, by a Y-axis driving unit, the substrate installation unit or the exposure lens as much as a specific distance in a Y-axis direction which is perpendicular to the X-axis direction and parallel to the plane direction; and repeating the step of radiating the laser beam and the step of changing the light quantity.
- [27] The method of manufacturing a phase-type diffraction element may further include the step of adjusting, by a focus adjustment unit, a focus of the exposure lens by adjusting a distance between the exposure lens and the substrate.
- [28] To accomplish a fifth object of the present invention, there is provided a phase-type diffraction element manufactured by the method of manufacturing a phase-type diffraction element described above.

Advantageous Effects of Invention

- [29] Therefore, according to an embodiment of the present invention described above, a phase-type diffraction element of a sine wave or a sawtooth wave having a desired re-

fractive index can be manufactured by radiating a laser beam, which can be adjusted in quantity, on a substrate formed of photo-curable resin.

[30] Further, since a Gaussian beam is used and the control unit controls the X-axis driving unit, the Y-axis driving unit and the rotation driving unit, a variety of sine wave phase-type diffraction elements of a desired type may be manufactured, and since the control unit controls the light quantity control unit, the X-axis driving unit, the Y-axis driving unit and the rotation driving unit, a phase-type diffraction element of a desired sawtooth wave may be manufactured.

[31] Although the present invention is described in relation to the preferred embodiments described above, those skilled in the art may easily recognize that a variety of changes and modifications can be made without departing from the scope and spirit of the present invention, and it is apparent that the changes and modifications are within the scope of the appended claims.

Brief Description of Drawings

[32] FIG. 1 is a cross-sectional view mimetically showing a laser beam penetrating an exposure lens and radiated on a photosensitive film in the prior art.

[33] FIG. 2 is a cross-sectional view mimetically showing a laser beam penetrating an exposure lens and radiated on the surface of a lens formed of photo-curable resin.

[34] FIG. 3 is a cross-sectional view showing a state of radiating a laser beam on the surface of a substrate formed of photo-curable resin.

[35] FIG. 4 is a cross-sectional view showing an apparatus for manufacturing a phase-type diffraction element using a direct laser exposure method according to an embodiment of the present invention.

[36] FIG. 5 is a cross-sectional view mimetically showing a Gaussian beam penetrating an exposure lens and radiated on the surface of a substrate formed of photo-curable resin.

[37] FIG. 6 is a graph showing a refractive index according to the cross section and the diameter of a Gaussian beam.

[38] FIG. 7 is a plan view of a substrate showing a radiation direction of a laser beam radiated by an apparatus for manufacturing a phase-type diffraction element using a direct laser exposure method according to a first embodiment of the present invention.

[39] FIG. 8 is a plan view showing a phase-type diffraction element manufactured by a method of manufacturing a phase-type diffraction element using a direct laser exposure method according to a first embodiment of the present invention.

[40] FIG. 9 is a cross-sectional view showing distribution of refractive index of a phase-type diffraction element manufactured by a method of manufacturing a phase-type diffraction element using a direct laser exposure method according to a first embodiment of the present invention.

- [41] FIG. 10 is a cross-sectional view of a substrate and an exposure lens showing a method of manufacturing a phase-type diffraction element using a direct laser exposure method according to a second embodiment of the present invention.
- [42] FIG. 11 is a plan view of a substrate showing a radiation direction of a laser beam radiated by an apparatus for manufacturing a phase-type diffraction element using a direct laser exposure method according to a second embodiment of the present invention.
- [43] FIG. 12 is a plan view showing a phase-type diffraction element manufactured by a method of manufacturing a phase-type diffraction element using a direct laser exposure method and a graph showing distribution of refractive index according to a second embodiment of the present invention.
- [44] FIG. 13 is a block diagram showing signal flow in a control unit of an apparatus for manufacturing a phase-type diffraction element using a direct laser exposure method according to an embodiment of the present invention.
- [45] FIG. 14 is a flowchart illustrating a method of manufacturing a phase-type diffraction element using a direct laser exposure method according to a second embodiment of the present invention.
- [46] <DESCRIPTION OF SYMBOLS>
- [47] 1: Laser beam 2: Gaussian beam
- [48] 3: Photosensitive film 4: Substrate
- [49] 5: Photo-curable resin substrate 6: Lens
- [50] 7: Phase-type diffraction element 8: Radiation direction
- [51] 9: Refractive index 10: Laser generation unit
- [52] 20: Light quantity control unit 21: Beam splitter
- [53] 22: Acousto-optic modulator 23: Photodiode
- [54] 24: Controller 30: Shutter
- [55] 40: Exposure head 50: Tilt mirror
- [56] 60: Laser diode 61: Optical detector
- [57] 62: Focus control unit 63: PZT driver
- [58] 70: Exposure lens
- [59] 80: Substrate installation unit 81: Substrate jig
- [60] 90: Rotation driving unit 91: Tilt table
- [61] 92: X-axis driving unit 93: Y-axis driving unit
- [62] 94 Control unit
- [63] 100: Apparatus for manufacturing phase-type diffraction element using direct laser exposure method

Best Mode for Carrying out the Invention

- [64] The preferred embodiments of the present invention that can be easily practiced by those skilled in the art will be hereafter described in detail with reference to the accompanying drawings. However, in describing the operating principles of the preferred embodiments of the present invention in detail, if already known functions or specific description of constitution related to the present invention may make the spirit of the present invention unclear, detailed description thereof will be omitted.
- [65] In the drawings illustrating the embodiments of the invention, elements having like functions will be denoted by like reference numerals and details thereon will not be repeated. Throughout the specification, when an element is connected to another element, it includes a case of indirectly connecting the elements with intervention of another element therebetween, as well as a case of directly connecting the elements. In addition, the concept of including a constitutional element means further including another constitutional element, not excluding another constitutional element, as much as an opposed description is not specially specified.
- [66] Hereinafter, the configuration of an apparatus 100 for manufacturing a phase-type diffraction element using a direct laser exposure method according to an embodiment of the present invention and a method of manufacturing a phase-type diffraction element using a direct laser exposure method according to the manufacturing apparatus 100 will be described. First, FIG. 4 is a cross-sectional view showing an apparatus 100 for manufacturing a phase-type diffraction element using a direct laser exposure method according to an embodiment of the present invention.
- [67] As shown in FIG. 4, the apparatus 100 for manufacturing a phase-type diffraction element using a direct laser exposure method according to an embodiment of the present invention includes a laser generation unit 10, a light quantity control unit 20, a shutter 30, an exposure head 40, a tilt mirror 50, a focus adjustment unit, an exposure lens 70, a substrate jig 81, a substrate installation unit 80, a rotation driving unit 90, an X-axis driving unit 92, and a Y-axis driving unit.
- [68] The quantity of laser beam 1 generated by the laser generation unit 10 (in a specific embodiment, an Argon (Ar) laser generator is used) is adjusted as the laser beam 1 passes through the light quantity control unit 20, and the laser beam 1 passes through the shutter 30 intermittently interrupting the laser beam 1 and enters into the exposure head 40. In a specific embodiment of the present invention, the light quantity control unit 20 may include an acousto-optic modulator 22, a beam splitter 21, a photodiode 23 and a controller 24 as shown in FIG. 4.
- [69] As shown in FIG. 4, the route of the laser beam 1 entered into the exposure head 40 is changed by the beam splitter 21, the tilt mirror 50 and the beam splitter 21, and the laser beam 1 passes through the exposure lens 70. The configuration of changing the route of the laser beam 1 by reflecting the laser beam using the tilt mirror is not limited

to the specific embodiment, but it can be changed depending on the structure of the exposure head 40 and the position of the exposure lens 70, and it is apparent that such a specific structure does not affect the scope of right of the present invention. As shown in FIG. 4, the apparatus 100 for manufacturing a phase-type diffraction element may include the tilt mirror 50 among the mirrors for changing the route and a tilt mirror angle adjustment unit for adjusting the angle of the tilt mirror 50.

[70] As shown in FIG. 4, the tilt mirror 50 angle adjustment unit may be configured of the photodiode 23 and the beam splitter 21. The beam splitter 21 reflects the laser beam 1 to put the laser beam into the tilt mirror 50 and penetrates the light radiated from the photodiode 23. The light emitted from the photodiode 23 passes through the beam splitter 21, and it is reflected by the tilt mirror 50 and enters into the photodiode 23 again, and thus the angle of the tilt mirror 50 is adjusted.

[71] In addition, the apparatus 100 for manufacturing a phase-type diffraction element using a direct laser exposure method according to an embodiment of the present invention may further include the focus adjustment unit. The focus adjustment unit may adjust the focus of the exposure lens 70 by changing the distance between the exposure lens 70 and a photo-curable resin substrate 5. The focus adjustment unit according to a specific embodiment includes a laser diode 60, a beam splitter 21, an optical detector 61, a focus control unit 62, and a PZT driver 63. A laser beam generated by the laser diode 60 is reflected by the beam splitter 21, passes through a beam splitter 21 placed at a lower position and enters into the exposure lens 70, and the laser beam reflected by the exposure lens 70 passes through both of the two beam splitters 21 and enters into the optical detector 61. The focus control unit 62 transmits a control signal to the PZT driver 63 based on the information on the reflected laser beam, and the PZT driver 63 changes the distance between the exposure lens 70 and the photo-curable resin substrate 5 by moving the exposure lens 70.

[72] The laser beam 1 passing through the exposure lens 70 is radiated on the photo-curable resin substrate 5 installed in the substrate installation unit 80 provided around the focus of the exposure lens 70. As is described below, the laser beam 1 corresponds to a Gaussian beam 2 in the first embodiment of the present invention, and a laser beam 1 having a uniform optical strength is used as a laser beam 1 according to a second embodiment.

[73] FIG. 5 is a cross-sectional view mimetically showing a Gaussian beam 2 penetrating an exposure lens 70 and radiated on the surface of a photo-curable resin substrate 5, and FIG. 6 is a graph showing a refractive index according to the cross section and the diameter of a Gaussian beam 2.

[74] As shown in FIGs. 5 and 6, the Gaussian beam 2 has an optical strength decreasing from the center toward the outer side and a refractive index having the largest at the

center and decreasing toward the outer side. Accordingly, if the Gaussian beam 2 is radiated on the photo-curable resin substrate 5, distribution of the refractive index of the photo-curable resin substrate 5 is changed, and a sine wave phase diffraction grating is formed.

[75] In addition, the apparatus 100 for manufacturing a phase-type diffraction element using a direct laser exposure method according to an embodiment of the present invention may include an X-axis driving unit 92, a Y-axis driving unit 93, and a rotation driving unit 90. As shown in FIG. 4, the X-axis driving unit 92 is provided at one side of the exposure head 40 and moves the exposure head 40 in the X-axis direction. The photo-curable resin substrate 5 is installed on the substrate installation unit 80, and the photo-curable resin substrate 5 can be fixed to the substrate installation unit 80 by the substrate jig 81.

[76] In addition, the apparatus 100 for manufacturing a phase-type diffraction element using a direct laser exposure method according to an embodiment of the present invention may further include a Z-axis driving unit for moving the substrate installation unit 80 in the Z-axis direction, i.e., the vertical axis direction. The rotation driving unit 90 is configured to rotate the substrate installation unit 80 on the Z-axis and may move the rotation driving unit 90 and the substrate installation unit 80, including the Y-axis driving unit 93 combined below the rotation driving unit 90, in the Y-axis direction as a set. In addition, the apparatus 100 may further include a tilt table 91 between the rotation driving unit 90 and the Y-axis driving unit 93 to change an angle of a rotation stage and the substrate installation unit 80 by tilting a rotation stage and the substrate installation unit 80.

Mode for the Invention

[77] Hereinafter, a method of manufacturing a phase-type diffraction element using a direct laser exposure method according to a first embodiment of the present invention will be described. The method uses the apparatus 100 for manufacturing a phase-type diffraction element using a direct laser exposure method described above.

[78] First, a Gaussian beam 2 having a specific width is generated by the laser generation unit 10, and the Gaussian beam 2 enters and passes through the exposure lens 70 provided in the exposure head 40. Then, the Gaussian beam 2 is radiated on the photo-curable resin substrate 5 installed at the focus of the exposure lens 70.

[79] Accordingly, the refractive index of the photo-curable resin substrate 5 on which the Gaussian beam 2 is radiated is changed. While the Gaussian beam 2 is radiated, the control unit 94 moves the exposure lens 70 in the X-axis direction by driving the X-axis driving unit 92. At this point, the control unit 94 adjusts the moving speed and moving distance by controlling the X-axis driving unit 92.

- [80] After moving the exposure lens 70 to a set distance in the X-axis direction, the control unit 94 moves the substrate installation unit 80 in the Y-axis direction as much as a specific distance by driving the Y-axis driving unit 93. Then, the control unit 94 moves again the exposure lens 70 in the X-axis direction as much as a set distance by driving the X-axis driving unit 92.
- [81] FIG. 7 is a plan view of a substrate showing a radiation direction 8 of a Gaussian beam 2 radiated by a method of manufacturing a phase-type diffraction element using a direct laser exposure method according to a first embodiment of the present invention.
- [82] If the Gaussian beam 2 is radiated on the photo-curable resin substrate 5 in the radiation direction 8, a sine wave phase diffraction grating is formed as the refractive index of the photo-curable resin is changed according to the refractive index of the Gaussian beam 2. FIG. 8 is a plan view showing a phase-type diffraction element 7 manufactured by a method of manufacturing a phase-type diffraction element using a direct laser exposure method according to a first embodiment of the present invention. FIG. 9 is a cross-sectional view showing distribution of refractive index 9 of a phase-type diffraction element 7 manufactured by a method of manufacturing a phase-type diffraction element using a direct laser exposure method according to a first embodiment of the present invention.
- [83] Accordingly, a sine wave phase-type diffraction element 7 can be manufactured by the method of manufacturing a phase-type diffraction element using a direct laser exposure method according to a first embodiment of the present invention.
- [84] Hereinafter, a method of manufacturing a phase-type diffraction element using a direct laser exposure method according to a second embodiment of the present invention will be described. This method also uses the apparatus 100 for manufacturing a phase-type diffraction element using a direct laser exposure method described above.
- [85] FIG. 10 is a cross-sectional view of a substrate and an exposure lens 70 showing a method of manufacturing a phase-type diffraction element using a direct laser exposure method according to a second embodiment of the present invention. FIG. 11 is a plan view of a photo-curable resin substrate 5 showing a radiation direction 8 of a laser beam 1 radiated by an apparatus for manufacturing a phase-type diffraction element using a direct laser exposure method according to a second embodiment of the present invention.
- [86] In addition, FIG. 12 is a plan view showing a phase-type diffraction element 7 manufactured by a method of manufacturing a phase-type diffraction element using a direct laser exposure method and a graph showing distribution of refractive index 9 according to a second embodiment of the present invention. FIG. 13 is a block diagram showing

signal flow in a control unit 94 of an apparatus 100 for manufacturing a phase-type diffraction element using a direct laser exposure method according to an embodiment of the present invention, and FIG. 14 is a flowchart illustrating a method of manufacturing a phase-type diffraction element using a direct laser exposure method according to a second embodiment of the present invention.

- [87] First, a laser beam 1 having a specific width is generated by the laser generation unit 10 S10. In the second embodiment, a laser beam 1 having a uniform optical strength is used. Then, the laser beam 1 generated by the laser generation unit 10 is adjusted to have a light quantity set by the light quantity control unit 20 S20.
- [88] Then, the laser beam 1 adjusted in quantity enters and passes through the exposure lens 70 provided in the exposure head 40 S30. Then, the laser beam 1 is radiated on the photo-curable resin substrate 5 installed in the substrate installation unit 80 provided at the focus of the exposure lens 70 S40. Accordingly, the refractive index of the photo-curable resin substrate 5 on which the laser beam 1 is radiated is changed S50.
- [89] Then, while the laser beam 1 is radiated on the photo-curable resin substrate 5, the control unit 94 moves the exposure head 40 in the X-axis direction as much as a set distance by driving the X-axis driving unit 92 S60. Accordingly, the refractive index of the area on which the laser beam 1 is radiated is changed.
- [90] Next, the control unit 94 moves the substrate installation unit 80 in the Y-axis direction, which is perpendicular to the X-axis direction and parallel to the plane direction, as much as a specific distance (a distance as much as the width of the laser beam 1) by driving the Y-axis driving unit 93 S70. In the specific embodiment, the light quantity is adjusted to be smaller than the initially set light quantity.
- [91] Then, the control unit 94 moves the exposure head 40 in the X-axis direction as much as a set distance by controlling the X-axis driving unit 92. Accordingly, the refractive index of the area on which the laser beam 1 is radiated is changed, and the refractive index is smaller than the initial value.
- [92] If these steps are repeatedly performed as many as a set number of times S80, a phase diffraction grating having a refractive index distributed in the shape of a minute step is manufactured. When the steps are repeated as many as the set number of times, the light quantity is changed to the initially set light quantity S100, and the steps S60, S70 and S80 are repeated until a desired phase-type diffraction element 7 is manufactured S90. A phase-type diffraction element 7 of a sawtooth wave shown in FIG. 12 as a whole can be manufactured by repeating these steps.
- [93] While the present invention has been described with reference to the particular illustrative embodiments, it is not to be restricted by the embodiments but only by the appended claims. It is to be appreciated that those skilled in the art can change or modify the embodiments without departing from the scope and spirit of the present

invention.

Claims

- [Claim 1] An apparatus for manufacturing a phase-type diffraction element using a direct laser exposure method, the apparatus comprising:
a laser generation unit for generating a laser beam having a specific width;
an exposure lens for penetrating the laser beam generated by the laser beam generation unit;
a substrate formed of photo-curable resin and installed at a focus of the exposure lens, on which the laser beam is radiated on, and a refractive index of which is changed by the laser beam; and
a driving unit for moving the substrate or the exposure lens in a plane direction.
- [Claim 2] The apparatus according to claim 1, wherein the laser beam is a Gaussian beam.
- [Claim 3] The apparatus according to claim 2, wherein a cross section of the Gaussian beam has an optical strength gradually decreasing from a center toward an outer circumference.
- [Claim 4] The apparatus according to claim 3, further comprising a substrate installation unit for installing the substrate, wherein the driving unit includes an X-axis driving unit for moving the substrate installation unit or the exposure lens in an X-axis direction which is parallel to the plane direction.
- [Claim 5] The apparatus according to claim 4, wherein the driving unit further includes a Y-axis driving unit for moving the substrate installation unit or the exposure lens in a Y-axis direction which is parallel to the plane direction and perpendicular to the X-axis direction.
- [Claim 6] The apparatus according to claim 5, wherein the driving unit further includes a rotation driving unit for rotating the substrate installation unit on a Z-axis which is a vertical axis.
- [Claim 7] The apparatus according to claim 6, further comprising a control unit for controlling a moving direction and a moving speed of the X-axis driving unit, the Y-axis driving unit and the rotation driving unit.
- [Claim 8] An apparatus for manufacturing a phase-type diffraction element using a direct laser exposure method, the apparatus comprising:
a laser generation unit for generating a laser beam having a specific width;
a light quantity control unit for adjusting light quantity of the laser

beam generated by the laser generation unit;
an exposure lens for penetrating the laser beam generated by the laser beam generation unit;
a substrate formed of photo-curable resin and installed at a focus of the exposure lens, on which the laser beam is radiated on, and a refractive index of which is changed by the laser beam; and
a driving unit for moving the substrate or the exposure lens in a plane direction.

[Claim 9] The apparatus according to claim 8, wherein the light quantity control unit includes an acousto-optic modulator, a beam splitter, a photodiode and a controller.

[Claim 10] The apparatus according to claim 8, further comprising a substrate installation unit for installing the substrate, wherein the driving unit includes an X-axis driving unit for moving the substrate installation unit or the exposure lens in an X-axis direction which is parallel to the plane direction.

[Claim 11] The apparatus according to claim 10, wherein the driving unit further includes a Y-axis driving unit for moving the substrate installation unit or the exposure lens in a Y-axis direction which is parallel to the plane direction and perpendicular to the X-axis direction.

[Claim 12] The apparatus according to claim 11, wherein the driving unit further includes a rotation driving unit for rotating the substrate installation unit on a Z-axis which is a vertical axis.

[Claim 13] The apparatus according to claim 12, further comprising a control unit for controlling a moving direction and a moving speed of the X-axis driving unit, the Y-axis driving unit and the rotation driving unit and controlling the light quantity control unit.

[Claim 14] The apparatus according to claim 1 or 8, further comprising a focus adjustment unit for adjusting the focus of the exposure lens by adjusting a distance between the exposure lens and the substrate.

[Claim 15] A method of manufacturing a phase-type diffraction element using a direct laser exposure method, the method comprising the steps of:
generating, by a laser generation unit, a Gaussian beam having a specific width;
passing the Gaussian beam through an exposure lens;
radiating the Gaussian beam on a substrate formed of photo-curable resin and installed at a focus of the exposure lens;
changing a refractive index of the substrate on which the Gaussian

beam is radiated;

driving, by a control unit, any one of an X-axis driving unit for moving a substrate installation unit or the exposure lens in an X-axis direction which is parallel to a plane direction, a Y-axis driving unit for moving the substrate installation unit or the exposure lens in a Y-axis direction which is perpendicular to the X-axis direction and parallel to the plane direction, and a rotation driving unit for rotating the substrate installation unit on a Z-axis which is a vertical axis; and

forming a sine wave phase diffraction grating on the substrate on which the Gaussian beam is radiated.

[Claim 16]

A method of manufacturing a phase-type diffraction element using a direct laser exposure method, the method comprising the steps of: generating, by a laser generation unit, a laser beam having a specific width;

adjusting, by a light quantity control unit, the laser beam to have a set light quantity;

passing the laser beam through an exposure lens;

radiating the laser beam on a substrate formed of photo-curable resin and installed at a focus of the exposure lens;

changing a refractive index of the substrate on which the laser beam is radiated;

radiating the laser beam on the substrate as wide as a set moving distance by controlling, by a control unit, an X-axis driving unit which moves a substrate installation unit or the exposure lens in an X-axis direction which is parallel to a plane direction;

moving, by a Y-axis driving unit, the substrate installation unit or the exposure lens as much as a specific distance in a Y-axis direction which is perpendicular to the X-axis direction and parallel to the plane direction; and

repeating the step of radiating the laser beam and the step of changing the light quantity.

[Claim 17]

The method according to claim 15 or 16, further comprising the step of adjusting, by a focus adjustment unit, a focus of the exposure lens by adjusting a distance between the exposure lens and the substrate.

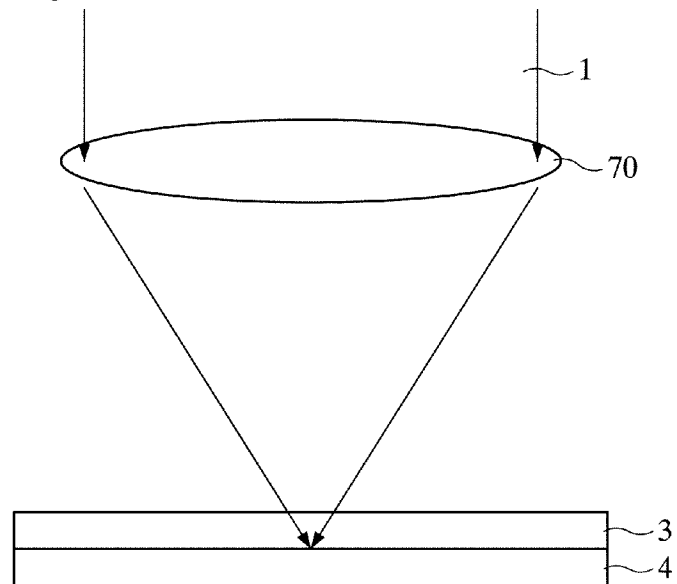
[Claim 18]

A phase-type diffraction element manufactured by the method of manufacturing a phase-type diffraction element according to claim 15.

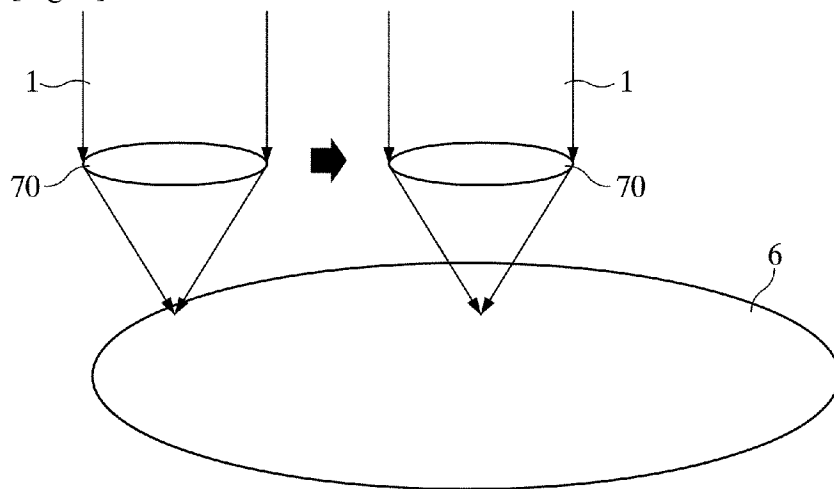
[Claim 19]

A phase-type diffraction element manufactured by the method of manufacturing a phase-type diffraction element according to claim 16.

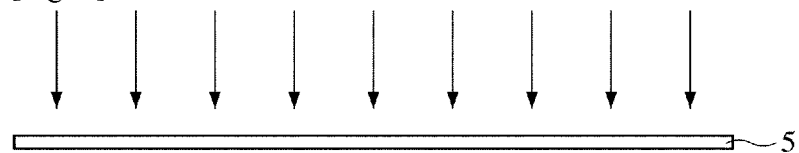
[Fig. 1]



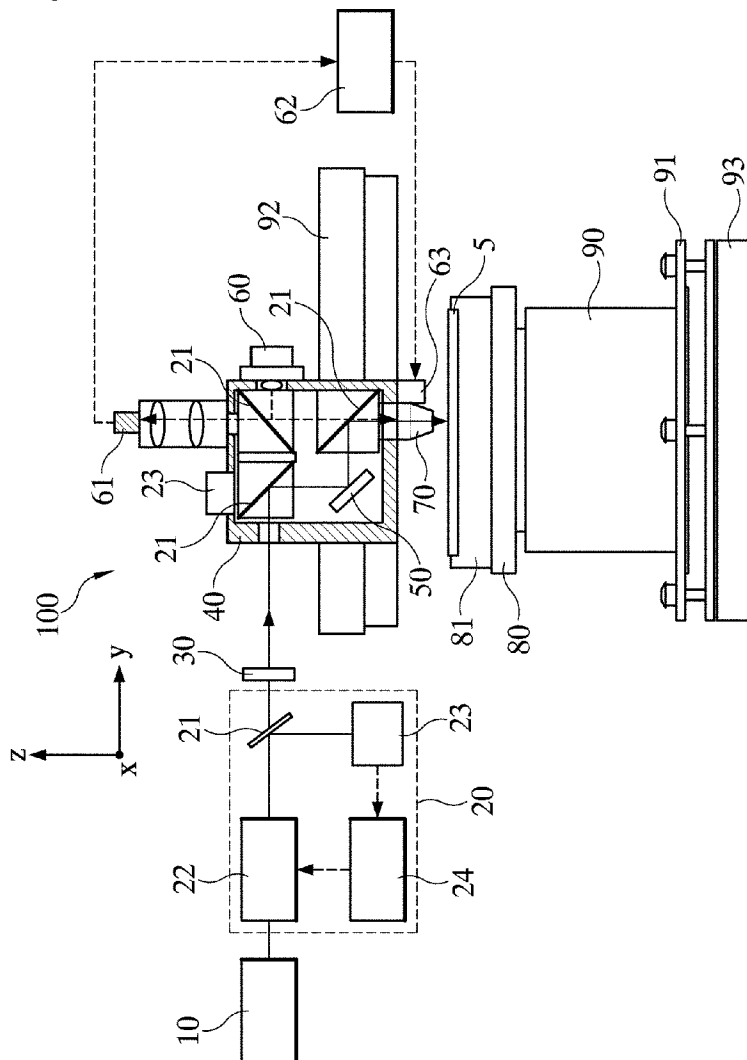
[Fig. 2]



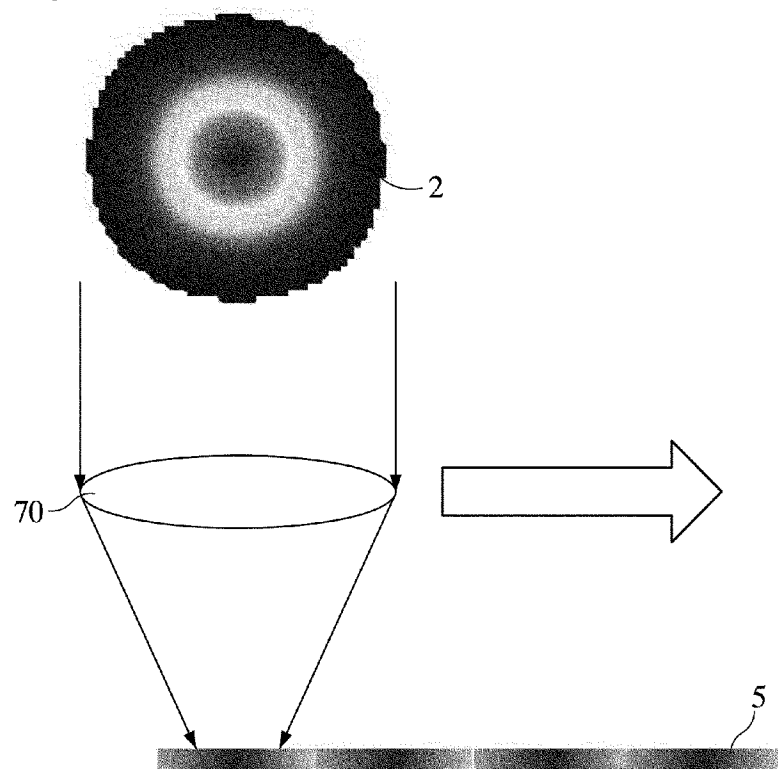
[Fig. 3]



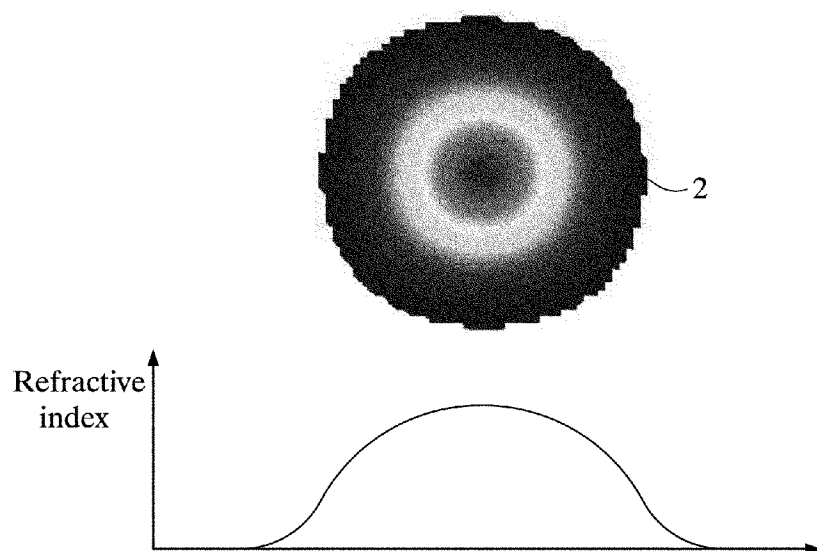
[Fig. 4]



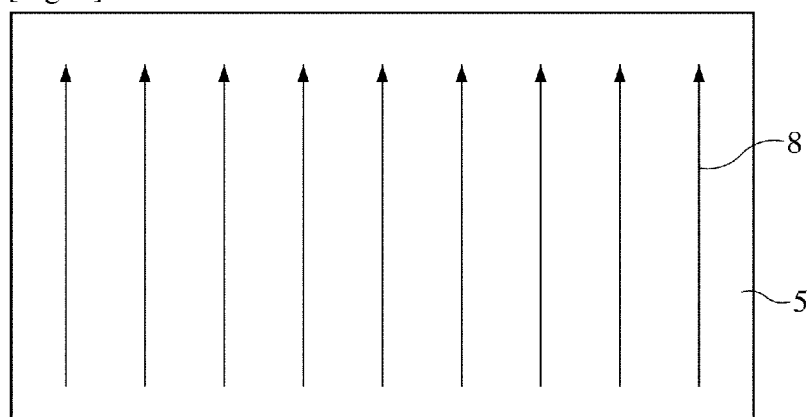
[Fig. 5]



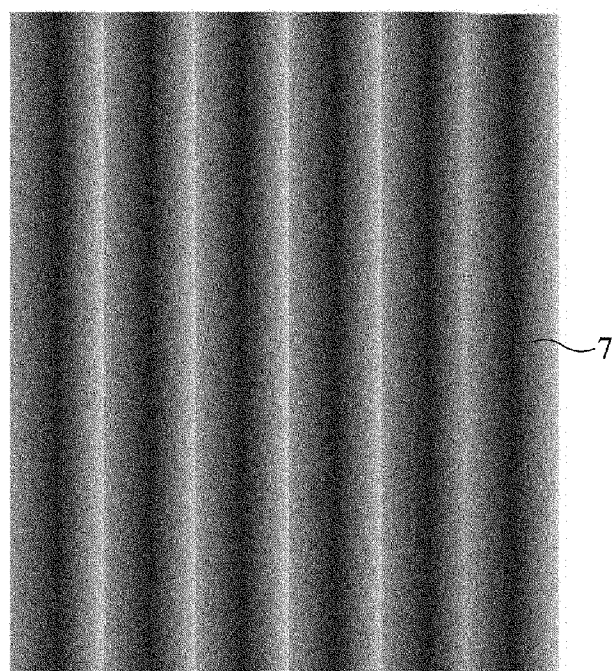
[Fig. 6]



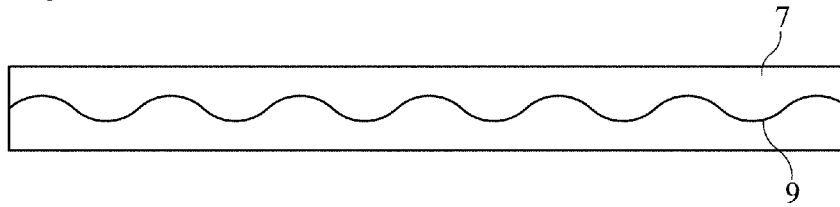
[Fig. 7]



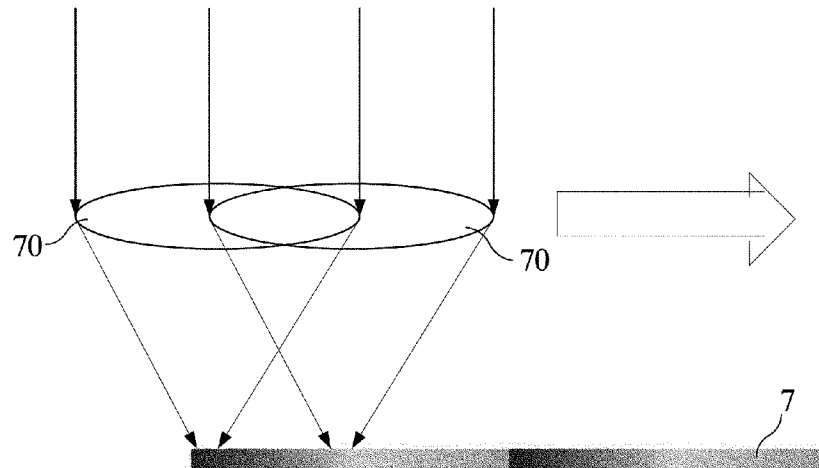
[Fig. 8]



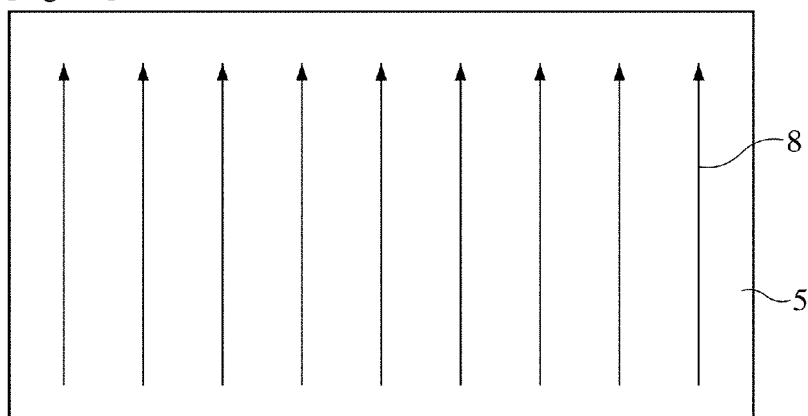
[Fig. 9]



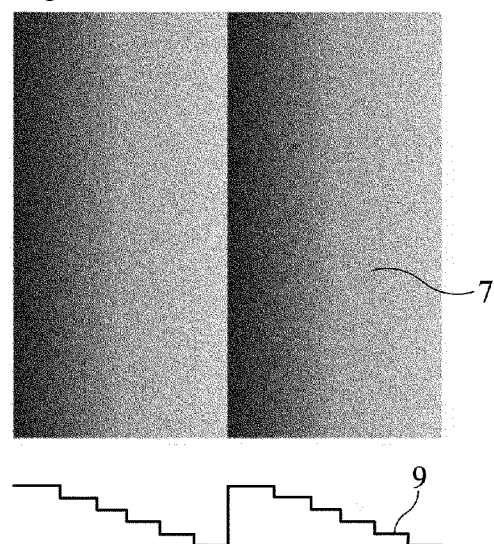
[Fig. 10]



[Fig. 11]

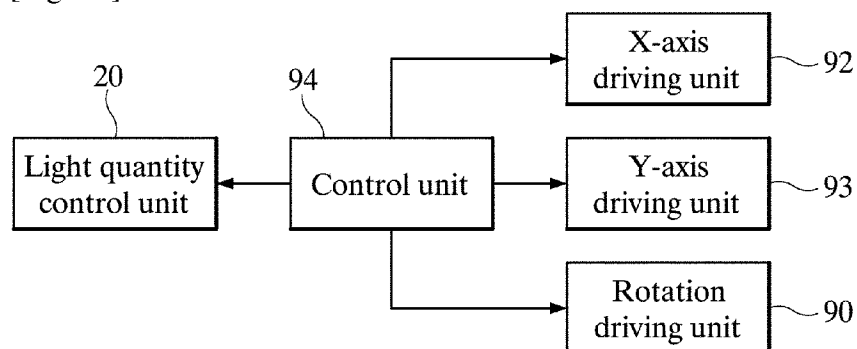


[Fig. 12]

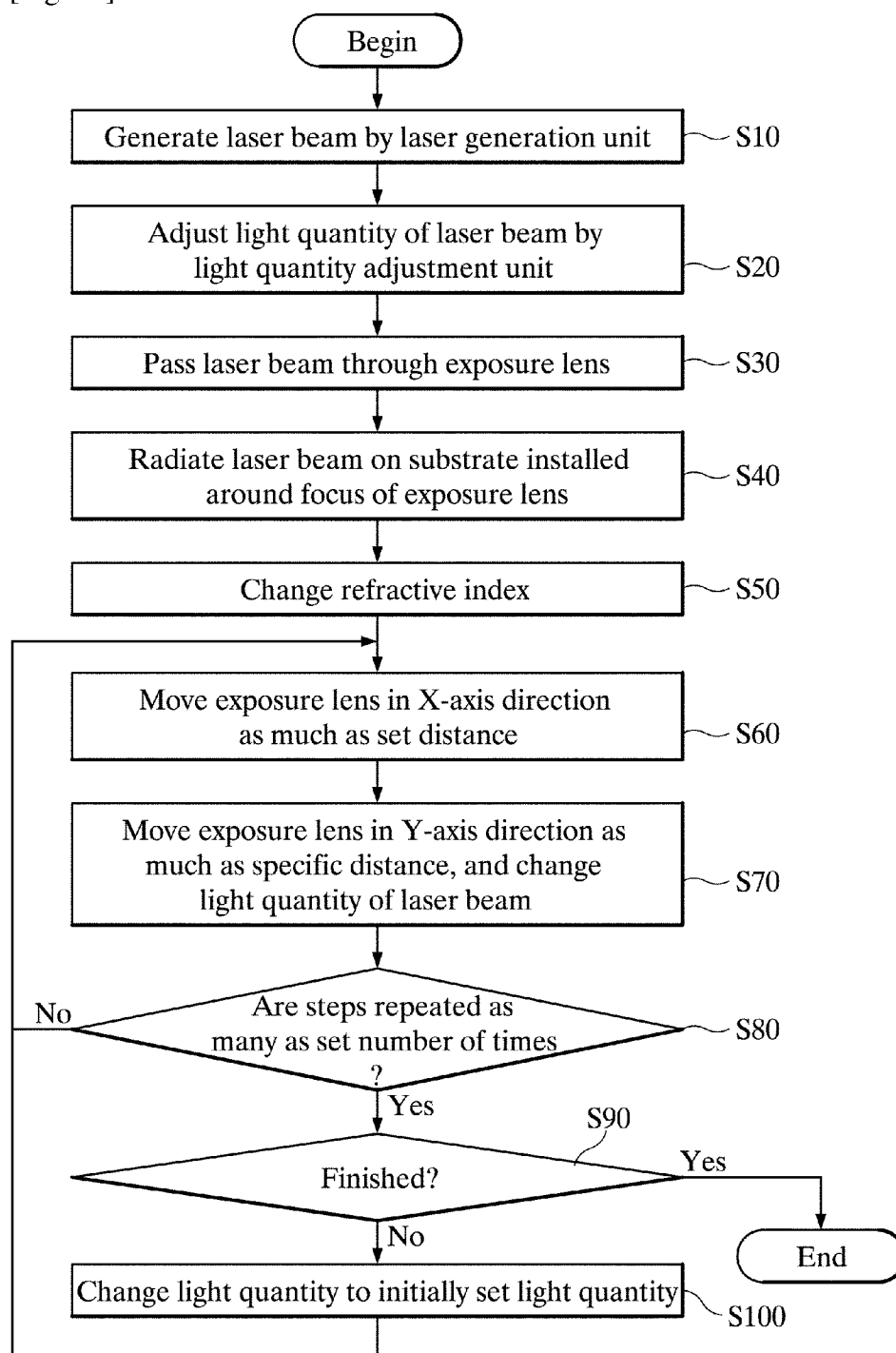


[Distribution of refractive index]

[Fig. 13]



[Fig. 14]



A. CLASSIFICATION OF SUBJECT MATTER**G02B 5/18(2006.01)i, G03F 7/26(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G02B 5/18; G03F 1/08; B41J 3/00; G03F 7/20; B23K 26/067; G03F 7/26

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: diffract, exposure, laser, grating, moving, refractive index, marking

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2002-0018076 A (SUMITOMO HEAVY INDUSTRIES, LTD.) 07 March 2002 See abstract; paragraphs [030] ~ [036], [039]; figures 1, 4 and 6.	1, 2-7, 15, 17, 18
Y		8-14, 16, 19
Y	JP 10-003002A (NIKON CORP) 06 January 1998 See abstract; paragraphs [002], [004], [010]; figure 1.	8-14, 16, 19
A		1-7, 15, 17, 18
A	JP 2004-045575 A (DAINIPPON PRINTING CO LTD) 12 February 2004 See abstract, paragraphs [007] ~ [011].	1-19
A	JP 2009-134287 A (SEIKO EPSON CORP) 18 June 2009 See abstract, paragraphs [002], [017]~[019].	1-19



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

07 October 2013 (07.10.2013)

Date of mailing of the international search report

08 October 2013 (08.10.2013)

Name and mailing address of the ISA/KR

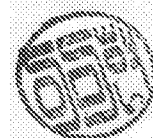
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2013/006711

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